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RADIOACTIVE ISOTOPIC CHARACTERIZATION OF THE ENVIRONMENT NEAR WISCASSET, MAINE USING PRE- AND POST-OPERATIONAL SURVEYS IN THE VICINITY OF THE MAINE YANKEE NUCLEAR REACTOR

Maine University at Arono

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U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Radiation Programs

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RADIOACTIVE ISOTOPIC CHARACTERIZATION OF THE ENVIRONMENT NEAR WISCASSET, MAINE USING PRE- AND POST-OPERATIONAL SURVEYS IN THE VICINITY OF THE MAINE YANKEE NUCLEAR REACTOR.

MAY 1976

ENVIRONMENTAL ANALYSIS DIVISION
OFFICE OF RADIATION PROGRAMS
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

THIS WORK WAS PERFORMED UNDER ENVIRONMENTAL PROTECTION AGENCY CONTRACT NUMBER 68-01-2654 BY THE UNIVERSITY OF MAINE, ORONO, MAINE, UNDER THE DIRECTION OF DR. C. T. HESS, DR. C. W. SMITH, C. H. CHURCHILL AND G. F. BURKE.

PREFACE

The Office of Radiation Programs is concerned with the evaluation of radiation exposure to man and his environs. Nuclear power plants release radioactive materials to the environment from normal operations which become a potential source of exposure to the population. The Environmental Analysis Division has responsibilities for evaluating the environmental and public health impacts resulting from such releases.

This study was performed on contract to this Division by the University of Maine for the purpose of isotopic characterization of environmental radioactivity outside the plant site boundary of the Maine Yankee Pressurized Water Nuclear Power Reactor during 1973. It compares the pre-operational survey with the postoperational survey to determine the amount of contamination resulting from operations of this power reactor.

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RADIOACTIVE ISOTOPIC CHARACTERIZATION OF THE ENVIRONMENT NEAR WISCASSET, MAINE USING PRE- AND POST-OPERATIONAL SURVEYS IN THE VICINITY OF THE MAINE YANKEE NUCLEAR REACTOR

ABSTRACT

A comparison of identical surveys of the pre- and post-operational environmental radioactivity is made for the vicinity of the Maine Yankee Atomic Power Reactor, Wiscasset, Maine. Radionuclides are measured in laboratory samples of soil, sediment, well water, surface water, estuarine water, air particulate, air moisture, and precipitation. Field measurements of gamma-ray emitting radionuclides and high pressure ion chamber measurements are also presented. The changes in radionuclide concentration and dose are evaluated using the Maine Yankee Environmental Impact Statement. The most significant changes occur for radionuclides in soils and sediments. Details of the distribution of sediment radionuclides near the outflow of the reactor in Bailey Cove are presented with dose estimates of 10.6 mrem/year at the sites of greatest specific activity. Radionuclides in the water were mainly natural ^{222}Rn and daughters. Tritium concentrations were at minimum detectable level. Air particulate showed traces of ^{7}Be and $^{95}ZrNb$ at fallout levels which were not significantly different from the preoperational levels. High pressure ion chamber dose rates ranged from 8.9 to 12.6 μR/hr at the 12 measured sites.

Time variations of radionuclide content were measured for oysters cultured in the reactor effluent and associated sediments. Doses calculated for ingestion of radionuclides by consumption of oysters would be 0.27 mrem/yr for ^{58}Co and 0.004 mrem/yr for ^{54}Mn.

FORWARD

This report presents the procedures and results of an environmental radioactivity survey in the vicinity of the Maine Yankee Atomic Power Plant (a 855 MWE pressurized water reactor) 6.4 km south southwest of Wiscasset, Maine on Bailey Point. Prior to the operation of this facility measurements of environmental radioactivity were made (1972) on samples of soil, sediment, well water, surface water, estuarine water, air particulate, air moisture, and precipitation. The procedures and results of that survey were reported in "Radiation Data and Reports", volume 15, number 2, February 1974.

The post-operational survey (1974) represents the follow-up survey to the pre-operational survey referenced above. The study design employs the same techniques, environmental media, and sampling sites as the pre-operational survey. The objective of this dual survey is to assess changes in environmental radioactivity.

ACKNOWLEDGMENTS

The work reported here represents a cooperative effort by several institutions and facilities. Essential to this study was the work of the staff of the Eastern Environmental Radiation Facility, Montgomery, Alabama for off-site laboratory measurements, with special thanks to Mrs. Ann B. Strong, Mr. Charles Phillips and Mr. Thomas Reavey. We gratefully acknowledge the participation by the Ira C. Darling Center for Oceanographic Research, University of Maine in the estuarine aspects of this study, the transect study of Bailey Cove and the aquaculture of the oysters for the uptake modeling, with special thanks to Mr. A. H. Price and Dr. H. Hidu. Cooperation and assistance by the Maine Yankee Atomic Electric Company, with special thanks to Mr. V. Thompson, was gratefully appreciated. We acknowledge the use and cooperation of the University of Maine Physics Department, Computer Center and Office of Grant Support. The information included in this report as Appendix D was part of a study funded by the National Oceanic and Atmospheric Administration. We appreciate their willingness to have this material included in this report.

We are especially grateful for the useful discussions throughout this study with Mr. C. L. Weaver of EPA's Office of Radiation Programs and for the assistance of Mr. Charles Robbins of the Environmental Analysis Division who coordinated the publication of this report.

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1. INTRODUCTION

1.1 Purpose of the Study

This study consists of a pre-operational (1972) and post-operational (1974) environmental radioactivity survey in the vicinity of the Maine Yankee Nuclear Power Reactor (6.4 km S.S.W. of Wiscasset, Maine on Bailey Point, See Fig. 1). The study measures any changes in the radionuclide content of the soil, estuarine sediment, estuary, well, and surface water, air moisture precipitation, and air particulate for this region. The study identifies the pathways in these environmental media which tend to collect or reconcentrate radionuclides and the regions in which reconcentration occurs.

1.2 Goals for this Study

A. To broadly survey several environmental media (soil, sediment, water, air moisture and air particulate) for changes in radionuclide content (nuclide by nuclide rather than gross activity) resulting from the operation and refueling of the Maine Yankee Nuclear Power Reactor.

B. To compare observed changes with the Maine Yankee Semi-annual Report of Release of Radioactive Materials[1] and with predictions of the Maine Yankee Environmental Impact Statement[2].

C. To examine in detail the largest change observed in the study.

1.3 Study Design

Studies of pressurized water reactors as outlined by Kahn[3], Rowe[4] and Lentsch[5] et.al. are based on a combination of knowledge of radionuclide releases, use of very sensitive environmental measurements and a carefully planned pre-operational survey. This study similarly employs these features. A nuclide by nuclide comparison of a pre-operational and post-operational survey of several environmental media forms the overall structure of this study. Field and laboratory measurements of primarily gamma-ray emitting radionuclides were used to determine which of the radionuclides listed in the Semi-annual Report of Release of Radioactive Materials[1] are being retained in the environment in the vicinity of the reactor. Tritium, gross beta and gross alpha measurements, along with high pressure ion chamber measurements also were employed. The major radionuclide in the liquid effluent is tritium and the major radionuclides in the gaseous effluent is ^{133}Xe and tritium. Several other radionuclides in trace amounts (See Appendix A) are also released in the liquid and gaseous effluents.

To achieve both the sensitivity and diversity of measurements to cover this broad survey this study utilized the facilities of the Eastern Environmental Radiation Facility, Montgomery, Alabama for laboratory measurements for the post-operational survey, the Northeastern Radiological Health Laboratory, Woburn, Massachusetts for laboratory measurements for the pre-operations survey and the University of Maine, Department of Physics for the field measurements and some laboratory measurements for both surveys[6,7]. The two surveys employ the same sampling sites and as far as possible the same or similar instrumentation. Details of each measurement are presented

in the following sections along with the experimental results. Post-operational and pre-operational resu ts are presented in tables in each section. Comparisons are made, changes are discussed and conclusions are presented in each section. The largest change was observed for sediments in the Bailey Cove estuary and is presented as Section 2.14 Sediment Transect Survey and Analysis.

2.1 RADIONUCLIDES IN THE SOIL AND SEDIMENT

2.11 Laboratory Soil and Sediment Measurements and Their Analysis

Soil samples were collected at the following sites: (Foxbird Island, 0.1 km, S.; Eaton Farm, 0.4 km, W.; Bailey Farm, 0.8 km, N.E.; Young's Creek, 1.0 km, N.; Knight Cemetary, 1.1 km, E.; Westport Firehouse , 1.8 km, S.; Chewonki Neck (Camp), 1.9 km, S.W.; Cowseagan Narrows, 3.2 km, N.E. and Bluff Head, 4.0 km, S.S.W., see map). Sediment samples were collected at Foxbird Island, 0.1 km, S, on the outfall side of the causeway and at Murphy's Corner, 2.8 km, S.W. Soil samples were collected using a disc-cutter sampler which would cut a cylindrical soil sample 15 cm in diameter by 15 cm deep. Four soil samples this size, each centered at the corner of a square grid 25 cm on an edge were collected at each of the nine sites. The four soil samples including surface vegetation were mixed and the root mats pulverized. The sample was then screened and all material smaller than 5 mm retained. The sample was then dried at 110°C for 24 hours. In the case of the sediment samples, the top two centimeters were collected. These samples were screened and dried in an identical manner. In each case the samples were divided and a dry kilogram of the sample material was shipped to the Eastern Environmental Radiation Facility, Montgomery, Alabama for gamma-ray analysis using a Ge(Li) detector and on-line computer-analyzer. Analysis was carried out by hand using the Compton continuum subtraction method[8]. All samples were counted for a nominal 900 minutes (with a nominal 10 persent dead time) with a 2048 channel analysis. The results of the analysis are listed in Table I. The results of the pre-operational analysis are listed in Table II.

TABLE I
POST-OPERATIONAL LABORATORY SOIL AND SEDIMENT GAMMA-RAY ANALYSIS

SAMPLE IDENTIFICATION				THORIUM SERIES	URANIUM SERIES	OTHER NATURAL	RADIONUCLIDES				
LOCATION	DATE COLLECTED	DATE COUNTED	TYPE	^{228}Ac pCi/kg ±2σ	^{214}Bi pCi/kg ±2σ	^{40}K pCi/kg ±2σ	^{137}Cs pCi/kg ±2σ	^{134}Cs pCi/kg ±2σ	^{58}Co pCi/kg ±2σ	^{60}Co pCi/kg ±2σ	^{54}Mn pCi/kg ±2σ
Foxbird Island	8/14/74	11/16/74	soil	900 ±90	700 ±200	7300 ±950	4600 ±180	< 35	< 25	< 30	< 15
Eaton Farm	8/14/74	11/18/74	soil	1100 ±120	1100 ±120	17400 ±1200	2500 ±130	< 35	< 25	< 30	< 15
Bailey Farm	8/14/74	11/20/74	soil	1100 ±150	1100 ±170	17600 ±1300	1800 ±100	< 35	< 25	< 30	< 15
Young's Creek	8/14/74	11/18/74	tidal marsh soil	1100 ±120	800 ±70	19400 ±780	700 ±50	< 35	< 25	< 30	< 15
Knight Cemetery	8/14/74	11/19/74	soil	1700 ±225	1300 ±180	11300 ±1300	4000 ±160	< 35	< 25	< 30	< 15
Westport Firehouse	8/14/74	11/17/74	soil	800 ±90	800 ±100	11800 ±700	3200 ±100	< 35	< 25	< 30	< 15
Chewonki Neck(Camp)	8/14/74	11/14/74	soil	900 ±90	700 ±80	15100 ±600	1500 ±50	< 35	< 25	< 30	< 15
Cowseagan Narrows	8/14/74	11/15/74	soil	1000 ±70	1000 ±100	14300 ±570	1300 ±50	< 35	< 25	< 30	< 15
Bluff Head	8/14/74	11/19/74	soil	1200 ±48	1600 ±80	13300 ±530	1200 ±50	< 35	< 25	< 30	< 15
Foxbird Island	8/14/74	11/15/74	tidal marsh sediment	900 ±300	900 ±270	20500 ±1600	1000 ±130	1000 ±130	21000 ±400	2420 ±250	450 ±100
Murphy's	8/14/74	11/20/74	tidal flat sediment	900 ±90	800 ±72	18000 ±500	500 ±35	< 35	< 25	< 30	< 15

All measurements based on dry weight

TABLE II
PRE-OPERATIONAL LABORATORY SOIL AND SEDIMENT GAMMA-RAY ANALYSIS

SAMPLE IDENTIFICATION				THORIUM SERIES	URANIUM SERIES	OTHER NATURAL	RADIONUCLIDES				
LOCATION	DATE COLLECTED	DATE COUNTED	TYPE	^{228}Ac pCi/kg ±2σ	^{214}Bi pCi/kg ±2σ	^{40}K pCi/kg ±2σ	^{137}Cs pCi/kg ±2σ	^{134}Cs pCi/kg ±2σ	^{58}Co pCi/kg ±2σ	^{60}Co pCi/kg ±2σ	^{54}Mn pCi/kg ±2σ
Foxbird Island	6/29/72	7/20/72	soil	1200 ±100	700 ±90	14000 ±1000	940 ±85	< 30	< 25	< 30	< 20
Eaton Farm	6/12/72	7/17/72	soil	340 ±120	630 ±70	14900 ±400	870 ±45	< 15	< 12	< 15	< 10
Bailey Farm	6/12/72	7/12/72	soil	1240 ±300	810 ±150	14600 ±1300	1670 ±110	< 30	< 25	< 30	< 20
Young's Creek	6/12/72	7/14/72	tidal marsh soil	880 ±250	1075 ±120	18200 ±400	800 ±80	< 30	< 25	< 30	< 20
Knight Cemetery	6/12/72	6/26/72	soil	1210 ±200	700 ±80	11200 ±1200	4960 ±110	< 30	< 25	< 30	< 20
Westport Firehouse	6/12/72	6/21/72	soil	1000 ±350	920 ±120	11800 ±900	1110 ±85	< 30	< 25	< 30	< 20
Chewonki Neck(Camp)	6/12/72	7/20/72	soil	1100 ±250	1370 ±300	13200 ±1200	3340 ±130	< 30	< 25	< 30	< 20
Cowseagan Narrows	6/13/72	7/24/72	soil	300 ±300	730 ±180	13400 ±1250	2620 ±130	< 30	< 25	< 30	< 20
Bluff Head	6/12/72	6/22/72	soil	660 ±300	1100 ±180	11300 ±1240	2030 ±110	< 30	< 25	< 30	< 20
Foxbird Island	6/29/72	7/28/72	tidal marsh sediment	250 ±130	500 ±180	15000 ±350	350 ±32	< 15	< 12	< 15	< 10
Murphy's Corner	7/3/72	7/27/72	tidal flat sediment	1660 ±280	740 ±120	15200 ±1200	450 ±80	< 30	< 25	< 30	< 20

The Thorium series as represented by ^{228}Ac is found to be the same ($\pm 2\sigma$) as the pre-operational measurements with significant changes only at Eaton Farm soil. At present there is no obvious explanation of the difference. The Uranium series as represented by ^{214}Bi is found, in all cases, to be the same ($\pm 2\sigma$) as pre-operational measurements. The concentration of ^{40}K is found to be the same ($\pm 2\sigma$) for all cases except Foxbird Island soil and Foxbird Island sediment. In the case of Foxbird Island soil, a decrease is observed and for Foxbird Island sediment, increase is observed. ^{137}Cs is observed to be the same ($\pm 2\sigma$) in all cases except Foxbird Island soil, Eaton Farm soil, Westport Firehouse soil, Chewonki Neck soil, Bluff Head soil, and Foxbird Island sediment. Finally, ^{134}Cs, ^{58}Co, ^{60}Co and ^{54}Mn are all found to be present in Foxbird Island sediment. These four isotopes were not present in the sediment at the time of the pre-operational study.

This change is not in agreement with the Maine Yankee Environmental Impact Statement[2]. Specifically, page V-15, states - "Recreational and other uses of shorelines and waters near the plant will be permitted by the Applicant. Therefore, direct exposure to radiation from nuclides in the waters of the bay will be experienced. The individual receiving the highest radiation dose would probably be one who earns his livelihood by digging blood and sand worms in the mud flats in the vicinity of the reactor discharge. For this calculation, concentrations of radionuclides deposited on the mud flats were assumed to result from undiluted effluent water. Such a person was also postulated to be exposed to the mud flats for 2000 hr/yr. Based on these assumptions, the dose to the total body from radionuclides associated with the mud would be about 6 mrem per year for the individual receiving maximum exposure. Nearly all this exposure is from ^{134}Cs and ^{137}Cs deposited on the mud flats where the worms are harvested. The exposure to the hands of the worm diggers would be somewhat higher than their total-

body exposure since they sift through the mud while harvesting the worms."

We find that over (0.92) of the exposure will come from ^{54}Mn, ^{58}Co and ^{60}Co with the remaining portion (.08) coming from ^{134}Cs and ^{137}Cs. Furthermore, high pressure ion chamber measurements at Foxbird Island and Murphy's Corner show an increase of the intensity over sediment. At Foxbird Island, for example, this change in intensity is 5.3 (6.58)calc microrem per hour which comes to a dose change (for the 2000 hr/yr worm digger) of 10.6 (13.6)calc millirem per year. See Section 2.4 High Pressure Ion Chamber for details of these measurements. The range and extend of radionuclides in the sediment are presented in greater detail in Section 2.14 Sediment Transect Survey and Analysis.

2.12 Field Soil and Sediment Measurements and their Analysis

As prescribed by our pre-scans of soil samples described in 2.11 radionuclides in the soil were measured in the field at the following six locations. (Foxbird Island, 0.1 km, S.; Eaton Farm, 0.4 km, W.; Bailey Farm, 0.8 km, N.E.; Westport Firehouse, 1.8 km, S.; Chewonki Neck (Camp), 1.9 km, S.W.. On-site sediment measurements were taken at low tide at Murphy's Corner, 2.9 km, S.W. the location of a tidal mud flat of commercial importance to the local blood worm industry and Foxbird Island the site of the outflow. A portable multichannel analyzer system with a 5 cm by 5 cm NaI(T1) detector was employed. The portable multichannel analyzer system consisted of a Northern Scientific, Inc. NS-710 multichannel analyzer powered by a Cornell-Dubilier Powercon sine wave inverted Model 12ESW25 and a 12 v.d.c., 96 amp-hour battery. The detector, a 5 cm by 5 cm NaI(T1) crystal was an integral crystal-photomultiplier assembly by Teledyne Isotopes, Inc., Model S-88-I with 8.4 percent resolution at the ^{137}Cs photo-peak. It was powered by a Northern Scientific, Inc. high voltage battery power pack NS-308 with a matched cable-base assembly NS-309. The detector was connected to the multichannel analyzer with 50 m of coaxial cable (RG-59). A 100 lb. lead shield consisted of a cylinder 28 cm high, and 18 cm in diameter with a 6 cm diameter concentric hole the full length of the cylinder. The detector was housed in this shield for each on-site measurement. The shield was placed on the ground, the detector lowered into the shield and a 3 cm thick lead cap covered the upper end of the shield. The lower end of the shield was open to the soil so that the circular face of the detector was placed on the ground (a 1/8 inch insulating layer of plywood was used to protect the crystal from thermal shock). All

field soil and sediment gamma-ray spectra were taken using this top shielded 2π geometry[7]. It is felt that this geometry has two advantages: (i) it is reproducible and (ii) it is without bias in that it samples the soil in a nondestructive non-mixed manner. All field soil and sediment spectra were taken on one quarter memory (512 channels) for 4000 seconds. At the end of 4 runs the multichannel analyzer was returned to the University of Maine, Physics Department and the memory outputted into a model KSR-33 teletype. The teletype provided a listing of the counts in each channel and a punched paper tape. The punched paper tapes were converted into cards and the gamma spectra analyzed at the University of Maine Computer Center. The least squares method was used to obtain the best estimates of the amounts of each radionuclide present in each sample and an evaluation of the errors of these results. The computer program used was the Oak Ridge National Laboratory spectrum fitting program, Alpha-M[9]. It employs the least squares method to analyze the data for which a "best fit" is mathematically computed such that the sum of the squares of the deviations between the actual spectra and the "best fit" is minimized. The program also uses automatic gain shift and automatic threshold shift routines to optimize the fit. The program works with a library of standard spectra from which it synthesizes the "best fit" spectra. The library used for the analysis of the soil and sediment on-site spectra was composed of standard spectra for ^{40}K, ^{137}Cs, the ^{232}Th series, ^{134}Cs, ^{58}Co, ^{60}Co, and the ^{238}U series. Output from the program consists of the estimated amount of each standard spectra needed to synthesize the sample spectrum, the estimated error in the amount used for each library standard, the gain shift (if any) used to match the spectrum to the standards, the threshold or zero shift (if any) used to match the spectrum to the standards, the residuals for each channel and a listing of suspicious channels whose residuals lie outside two standard deviations.

In all cases convergence was obtained in less than 20 iterations. The results of the analysis are listed in Table III. Table IV lists results from the pre-operation survey.

One can see that in general all spectra contained ^{40}K, and the natural decay series for ^{232}Th and ^{238}U. A significant amount of ^{137}Cs, a non-natural isotope, is contained in all spectra. The field measurements at Foxbird Island tidal mud flats indicates ^{58}Co, and ^{60}Co at this site. Comparison of the levels of natural isotopes ^{232}Th, ^{238}U and ^{40}K and ^{137}Cs which is partly due to fallout are similar to pre-operational levels: with the exception of the Foxbird Island measurement which had more ^{238}U, ^{232}Th and less ^{137}Cs, and may be due to disturbances done by nearby construction of a diffuser for the reactor. Eaton Farm also shows more ^{238}U series and is not explained.

Measurements at Foxbird Island and Murphy's Corner show ^{58}Co and ^{60}Co. ^{60}Co was also measured at Bailey Farm and Knight Cemetery while ^{58}Co was measured at Eaton Farm. These cobalt isotopes were not present at the time of the pre-operational study. Measurements at Foxbird Island indicate ^{238}U and ^{232}Th has increased and ^{137}Cs decreased as compared to the pre-operational study. These changes in these three isotopes were probably caused by the extensive dust due to construction dredging trucking and back filling with estuarine sediment during construction of the diffuser channel and head basin.

TABLE III
POST-OPERATIONAL FIELD SOIL AND SEDIMENT GAMMA-RAY ANALYSIS

LOCATION	DATE MEASURED	TYPE	^{232}Th pCi/kg ±2σ	^{238}U pCi/kg ±2σ	^{40}K pCi/kg ±2σ	^{137}Cs pCi/kg ±2σ	^{58}Co pCi/kg ±2σ	^{60}Co pCi/kg ±2σ
Foxbird Island	8/21/74	soil	2000 ±70	1250 ±120	17400 ±750	3800 ±230	< 30	150 ±90
Eaton Farm	8/22/74	soil	2300 ±80	1300 ±120	24700 ±740	2800 ±260	210 ±30	< 75
Bailey Farm	8/22/74	soil	2100 ±95	1000 ±130	18600 ±880	3380 ±370	< 30	60 ±90
Knight Cemetery	8/22/74	soil	3100 ±80	660 ±120	23200 ±790	6900 ±310	< 30	150 ±80
Murphy's Corner	8/22/74	sedi-ment	1300 ±40	280 ±50	11000 ±370	590 ±130	180 ±30	70 ±40
Foxbird Island	8/24/74	sedi-ment	1500 ±60	580 ±80	16500 ±470	1400 ±200	730 ±20	100 ±70

TABLE IV
PRE-OPERATIONAL FIELD SOIL AND SEDIMENT GAMMA-RAY ANALYSIS

LOCATION	DATE MEASURED	TYPE	THORIUM SERIES pCi/kg	URANIUM SERIES pCi/kg	^{40}K pCi/kg	^{137}Cs pCi/kg	^{58}Co pCi/kg	^{60}Co pCi/kg
Foxbird Island	6/29/72	soil	1600 ±100	600 ±100	14000 ±3500	3590 ±800	< 30	< 75
Eaton Farm	6/26/72	soil	2400 ±100	700 ±100	21000 ±5000	5600 ±2700	< 30	< 75
Bailey Farm	6/27/72	soil	2000 ±100	800 ±200	16000 ±6000	3300 ±600	< 30	< 75
Young's Creek	6/27/72	soil	1600 ±400	600 ±200	14000 ±9000	4000 ±1400	< 30	< 75
Knight Cemetery	6/27/72	soil	3100 ±300	600 ±200	20000 ±6000	9500 ±1600	< 30	< 75
Westport Firehouse	6/27/72	soil	1500 ±100	500 ±100	14000 ±3000	7600 ±2000	< 30	< 75
Chewonki Neck (Camp)	6/26/72	soil	1900 ±100	500 ±150	20000 ±4000	5000 ±1100	< 30	< 75
Cowseagan Narrows	6/27/72	soil	1700 ±100	500 ±100	15000 ±3000	5400 ±800	< 30	< 75
Bluff Head	6/28/72	soil	2000 ±100	800 ±300	16000 ±5000	6300 ±1400	< 30	< 75
Murphy's Corner	7/3/72	sediment	1400 ±100	400 ±200	9000 ±4000	7000 ±1900	< 30	< 75

2.14 Sediment Transect Survey and Analysis

As a result of the high readings for the pre-scan and *in situ* gamma-ray measurements of sediment from Foxbird Island and as a result of suggestions from our collaborator Mr. Charles Phillips of Eastern Environmental Radiation Facility, Montgomery, Alabama, we decided to make a survey along tidal transects of the sediments in Bailey Cove. Using the cooperative efforts of the Ira C. Darling Center for marine research and members of the bloodwoorm research project, under the direction of Marine Biologist A. H. Price, 50 samples of estuarine sediments were collected at 50 ft. transects in Baily Cove adjacent to the outflow of the reactor. The locations of the sites are shown in Figure 2. These sediments were counted for 5000 sec. using the University of Maine, Physics Department's Ge(Li) detector and low background shield. Results of the determination of the concentration of gamma-ray emitting isotopes in the sediment is shown in pCi/kg. Figures 3 and 4 illustrate activity maps for ^{58}Co and ^{60}Co, respectively. It should be noted that the highest levels of radioactivity are for the outflow site (29) and for the upper reaches of the cove. The constant picocurie lines seem to follow the flow of water out of the cove at low tide and into the upper cove at high tide and thus suggest that the isotopes are transported by the outflow water and reconcentrated into the sediments. This reconcentration is consistent with a diffusion theory for fallout radionuclides in sediments as suggested by Lerman[10] and with chemical precipitation of ^{58}Co in the effluent of reactors as suggested by Fukui[11]. Comparison of the average flow velocities of the water from the outflow suggests sedimentation as another mechanism which reconcentrates the nuclides. Some indication of

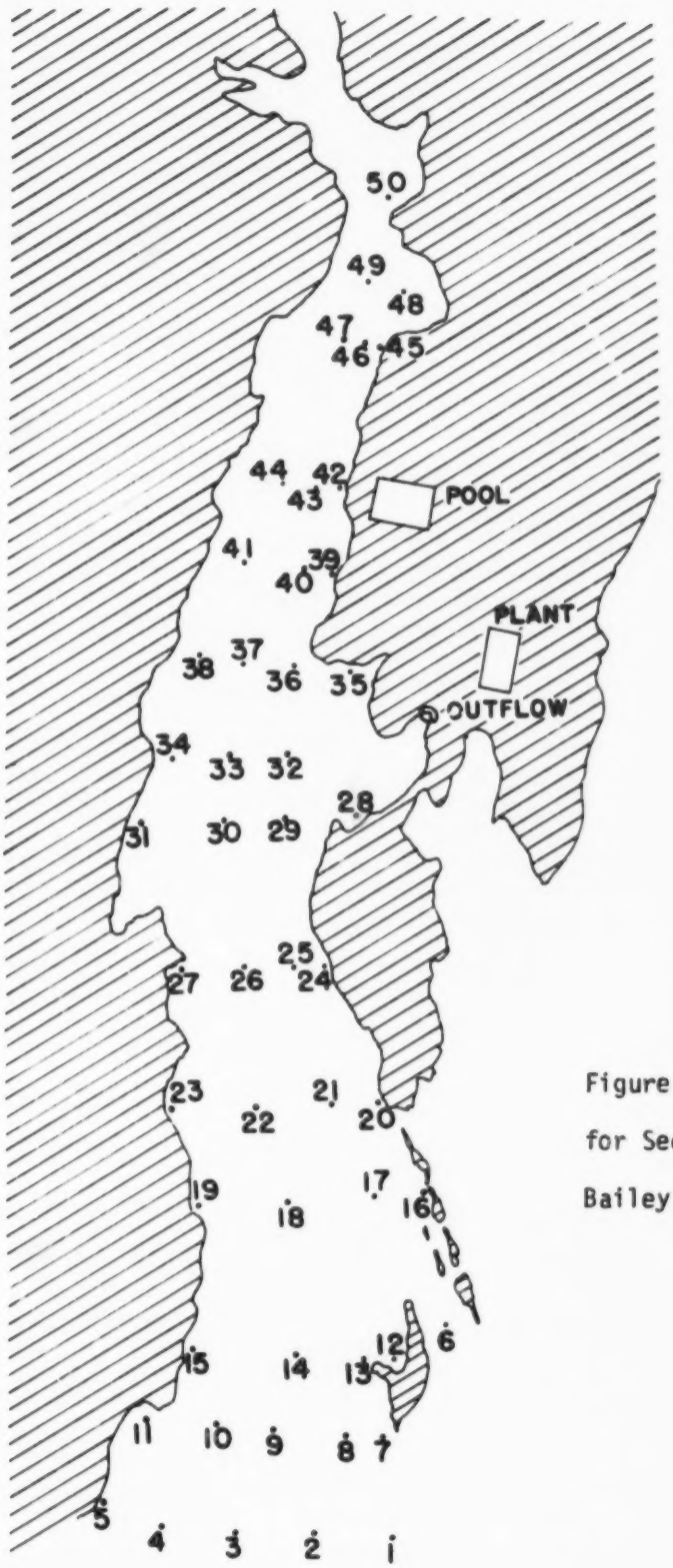

Figure 2, Site Locations for Sediment Transect Bailey Cove

175 meters

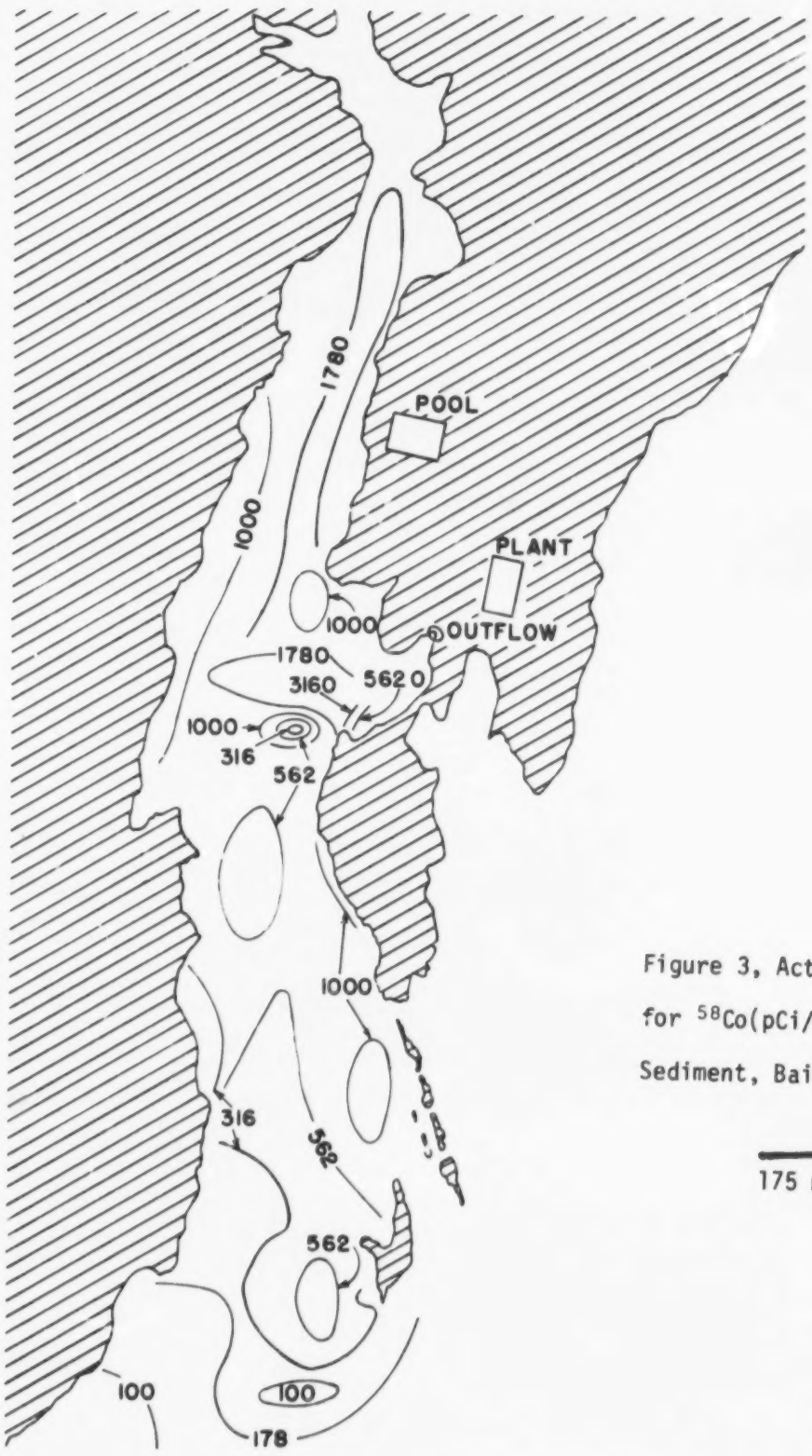

Figure 3, Activity Map for ^{58}Co(pCi/kg) in Sediment, Bailey Cove

175 meters

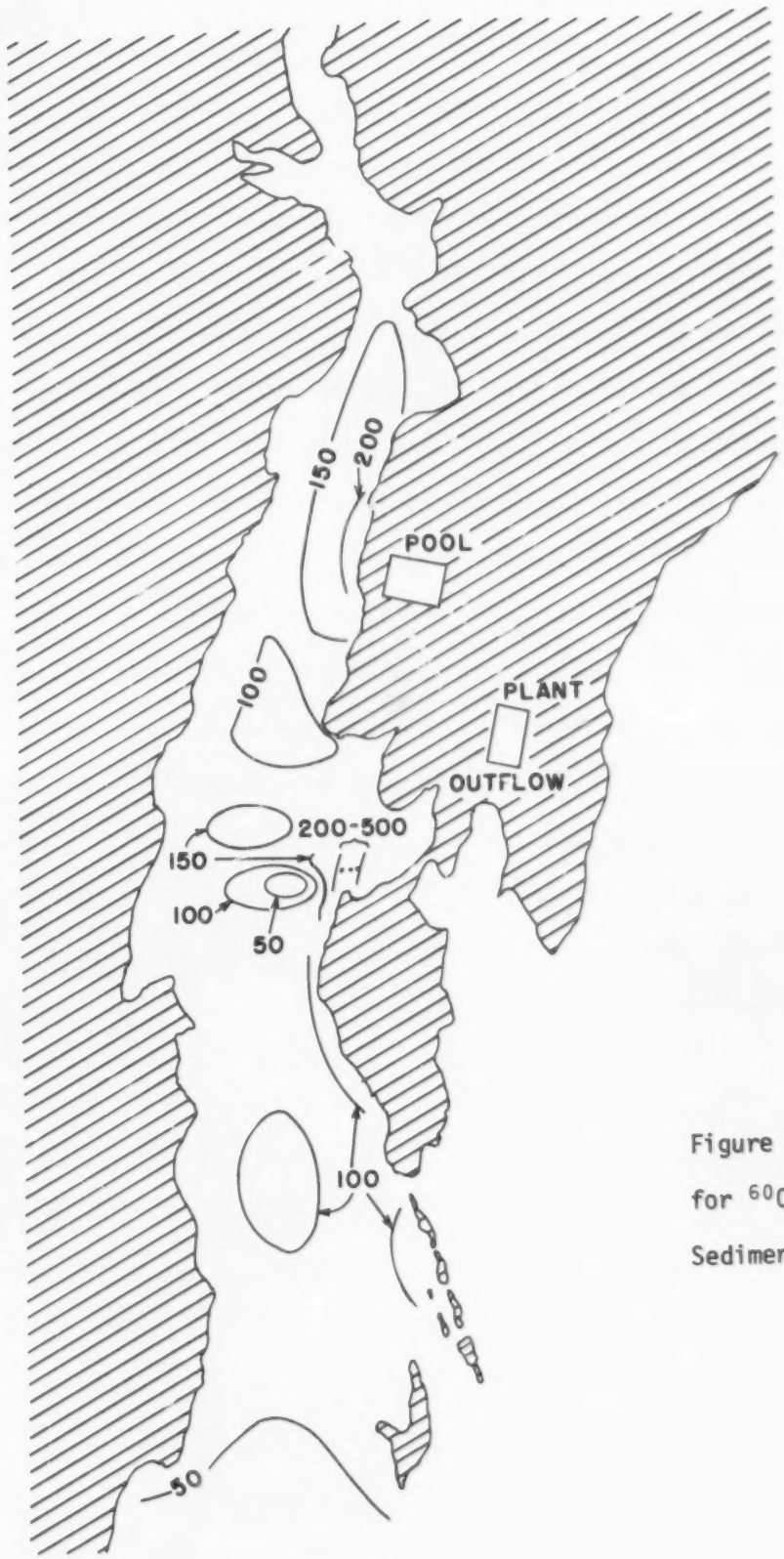

Figure 4, Activity Map for ^{60}Co(pCi/kg) in Sediment, Bailey Cove

175 meters

this may be seen in the reduced level of nuclides along the most direct channel of the outflow. The radionuclides ^{134}Cs, ^{137}Cs, and ^{60}Co bear this out by having similar behavior to the ^{58}Co. Since the Maine Yankee Environmental Impact Statement[2] does not specify range or distribution guidelines or estimates no comparison is made. However, implicit in the model[12] upon which the dose calculations were based is an assumption of uniform distribution of effluent discharge. This is not the case in the vicinity of Maine Yankee as shown by this transect survey in Bailey Cove. One radioactive particle containing 7700 pCi of ^{60}Co was observed in the sediment transect #19 and had a total activity (^{58}Co, 530 pCi: ^{46}Sc, 670 pCi: ^{54}Mn, 120 pCi) of more than 9000 pCi in a mass less than 20 μ grams. Photographs and x-rays powder patterns were made and it was found to be cubic cobalt, alpha iron, nickel, alpha and gamma manganese and possibly chromium and vanadium. This stainless steel like composition suggests reactor origin. The particle was also checked for the oxides, chlorides, nitrates, sulphates and hydroxides of these metals with negative results[13].

2.2 RADIONUCLIDES IN THE WATER

2.21 Field Water Measurements

Based upon the data obtained during the pre-operational field water measurements, the post-operational measurements showed no detectable amount of gamma activity above background. It is felt that field measurement of in-situ water with portable multichannel analyzer-detector equipment is significantly less sensitive than laboratory measurement and yields no additional information. Laboratory measurement, with the advantages larger detectors and massive shielding together with the practicality of longer measuring time, outweighs the advantages of preserving temperature, particulate and salinity gradients as is done in the laboratory water measurement.

2.22 Laboratory Water Measurements and Their Analysis

Water samples were collected at the following seven sites Foxbird Island, 0.1 km, S.; Eaton Farm, 0.4 km, W.; Bailey Farm, 0.8 km, N.E.; Young's Creek, 1.0 km, N.; Chewonki Neck (Camp), 1.9 km, S.W.; Cowseagan Narrows, 3.2 km, N.E.; and Bluff Head, 4.0 km, S.S.W., see map Figure 1. Each water sample was separated,by filtering the dissolved and the un-dissolved solids into two components. This separation was done in the field at the time of collection. The water was filtered using a Millipore high pressure filtering unit. A Milipore 90 mm filter holder was loaded with a Whatman No. 1 paper filter, a Millipore AP3207500 spacer, a Millipore SCWP09025 cellulose ester 8.0μ filter, a Millipore AP3207500 spacer and a Millipore HAWP09025 cellulose ester 0.45μ filter for each water sample. Ten liters of water from each site was filtered using the above arrangement.

The filtered water (dissolved component) was placed in one gallon plastic shipping containers to which 40 ml of nitric acid was added to stabilize the sample. Prior to acidification a 50 ml sample from each site was placed in a plastic bottle for tritium analysis, (see section 2.23). The dissolved component, (one gallon samples) and the undissolved component (filters) were sent to the Eastern Environmental Radiation Facility, Montgomery, Alabama for gamma-ray analysis.

The dissolved component was gamma-ray analyzed using a NaI(T1) detector and 3.5 liter Marinelli beaker geometry in a massive shield. The results of this analysis show no detectable gamma activity in the dissolved component. (See Appendix E for pre-operational laboratory dissolved water component).

The undissolved component was analyzed in the following manner. The filters were weighed before use. After use they were dried and reweighed to determine the amount of undissolved material. The filters were sent to the Eastern Environmental Radiation Facility, Montgomery, Alabama for gamma-ray analysis. The three filters for each site were first measured for gross alpha and gross beta activity and then counted in a 40 ml NaI(I1) well-crystal 10 cm x 13 cm with 3 cm deep well. The results of these measurements are presented in Table V. Table VI lists the results for the pre-operational survey.

TABLE V
POST-OPERATIONAL LABORATORY WATER MEASUREMENT
UNDISSOLVED COMPONENT (FILTER) COLLECTED 8/14/74

LOCATION	WATER TYPE	SAMPLE MASS (GRAMS)	GROSS ALPHA pCi/10 liters ±2σ	GROSS BETA pCi/10 liters ±2σ	GROSS GAMMA pCi/10 liters ±2σ
Foxbird Island	estuarine	0.165 ± 0.015	ND	1.4 ± 81%	ND
Eaton Farm	well	0.005 ± 0.015	18.9 ± 85%	2.6 ± 39%	ND
Bailey Farm	well	0.002 ± 0.015	60.7 ± 33%	21.1 ± 22%	ND
Long Ledge Creek (Young's Creek)	surface	0.621 ± 0.045	2.1 ± 59%	4.8 ± 59%	ND
Chewonki Neck (Camp)	well	0.005 ± 0.015	6.2 ± 66%	1.6 ± 57%	ND
Cowseagan Narrows	estuarine	0.122 ± 0.015	ND	1.3 ± 69%	ND
Bluff Head	estuarine	0.149 ± 0.015	ND	ND	ND

TABLE VI
PRE-OPERATIONAL LABORATORY WATER MEASUREMENT
UNDISSOLVED COMPONENT (FILTER) COLLECTED 6/13/72

LOCATION	WATER TYPE	SAMPLE MASS (GRAMS)	^{228}Ac	^{212}Bi	^{208}Tl	^{214}Pb	^{214}Bi	^{40}K
Foxbird Island	estuarine	0.131 ± 0.005	< 45	100 ±20	< 25	< 10	< 10	< 25
Eaton Farm	well	0.000 ± 0.005	< 45	< 10	< 25	30 ±25	< 10	< 25
Bailey Farm	well	0.007 ± 0.005	200 ±45	< 10	< 25	< 10	< 10	< 25
Long Ledge Creek (Young's Creek)	surface	0.045 ± 0.005	< 45	< 10	< 25	< 10	< 10	< 25
Chewonki Neck Camp	well	0.002 ± 0.005	< 45	< 10	< 25	< 10	< 10	< 25
Cowseagan Narrows	estuarine	0.114 ± 0.005	< 45	< 10	30 ±25	< 10	< 10	< 25
Bluff Head	estuarine	0.163 ± 0.005	< 45	< 10	70 ±25	< 10	< 10	< 25

2,22 Discussion of the Water Gamma-Ray Analysis

Several observations can be made from the data in Table V. The well water in this region of Maine contains considerable dissolved ^{222}Rn. This is due primarily to leaching from uranium oxide in the pegmatite deposits in the area. This is also reflected in the alpha and beta activity in the well water from the sites measured (Eaton Farm, Bailey Farm and to some extent Chewonki Neck Camp). In general the water measurements at all sites show no significant change from the pre-operational survey shown in Table VI and, with the exception of the well water, have typical activities for this type of environmental media. The specific activity of the undissolved component in the estuarine water is of the same magnitude as the specific activity in the estuarine sediments. The specific activity of the well water samples was about two orders of magnitude greater but from the pre-operational survey this is known to be of natural origin.

2.23 Tritium in the Water, Air Moisture and Precipitation

2.231 Tritium in the Water

Tritium in the water was measured in samples collected at the following seven locations, Foxbird Island, 0.1 km, S.; Eaton Farm, 0.4 km, W.; Bailey Farm, 0.8 km, N.E.; Young's Creek, 1.0 km, N.; Chewonki Neck (Camp) 1.9 km, S.W.; Cowseagan Narrows, 3.2 km, N.E. and Bluff Head, 4.0 km, S.S.W.; (see Fig. 1). Each water sample was filtered as described in section 2.2. A 50 milliliter sample from each site was sent to the Eastern Environmental Radiation Facility, Montgomery, Alabama for tritium analysis using the direct counting liquid scintillation method. The samples were counted in a low background chamber. The results of these post-operational measurements are presented in Table VII. Pre-operational measurements are presented in Table VIII.

TABLE VII

POST-OPERATIONAL TRITIUM IN WATER

LOCATION	DATE COLLECTED	TYPE	ACTIVITY nCi/l±2σ	INTERPRETED RESULT
Foxbird Island	8/15/74	estuarine	0.2 ± 0.2	at m.d.l.
Eaton Farm	8/15/74	well	< 0.2	below m.d.l.
Bailey Farm	8/15/74	well	0.2 ± 0.2	at m.d.l.
Long Ledge Creek (Young's Creek)	8/15/74	surface	0.3 ± 0.2	above m.d.l.
Chewonki Neck (Camp)	8/15/74	well	0.2 ± 0.2	at m.d.l.
Cowseagan Narrows	8/15/74	estuarine	< 0.2	below m.d.l.
Bluff Head	8/15/74	estuarine	< 0.2	below m.d.l.

The minimum detectable level (m.d.l.) for the analysis of tritium is 0.2 nCi/l.

TABLE VIII

PRE-OPERATIONAL TRITIUM IN WATER

LOCATION	DATE COLLECTED	TYPE	ACTIVITY nCi/l±2σ	INTERPRETED RESULT
Foxbird Island	6/13/72	estuarine	0.39 ± 0.2	zero
Eaton Farm	6/13/72	well	0.40 ± 0.2	zero
Bailey Farm	6/13/72	well	0.34 ± 0.2	zero
Young's Creek	6/13/72	surface	0.14 ± 0.2	zero
Chewonki Neck(Camp)	6/13/72	well	0.30 ± 0.2	zero
Cowseagan Narrows	6/13/72	estuarine	0.09 ± 0.2	zero
Bluff Head	6/13/72	estuarine	0.40 ± 0.2	zero

TABLE IX
POST-OPERATIONAL TRITIUM IN AIR MOISTURE

LOCATION	DATE COLLECTED	WATER QUALITY MEASURED	AIR VOLUME	MEASURED RESULTS ±2σ nCi/l WATER	INTERPRETED RESULTS nCi/l
Eaton Farm	8/27/74	32.8 ml	1280 l	< 0.2	zero
Bailey Farm	8/27/74	33.0 ml	1990 l	< 0.2	zero
Westport Firehouse	8/27/74	25.4 ml	1730 l	< 0.2	zero

TABLE X
PRE-OPERATIONAL TRITIUM IN AIR MOISTURE

LOCATION	DATE COLLECTED	WATER QUALITY MEASURED	AIR VOLUME	MEASURED RESULTS ±2σ nCi/l WATER	INTERPRETED RESULTS nCi/l
Eaton Farm	6/29/72	33.7 ml	2502.7 l	0.60 ± 0.2	0.6
Bailey Farm	6/15/72	33.1 ml	2000.0 l	19.1 ± 0.2	19.1
Westport Firehouse	6/27/72	33.4 ml	2500.0 l	0.60 ± 0.2	0.6

TABLE XI
POST-OPERATIONAL TRITIUM IN PRECIPITATION

LOCATION	DATE COLLECTED	TYPE	MEASURED RESULTS nCi/l±2σ	INTERPRETED RESULTS nCi/l
Eaton Farm	8/27/74	RAIN	< 0.2	zero
Bailey Farm	8/27/74	RAIN	0.3 ± 0.2	0.3
Knight Cemetery	4/9/74	SNOW	< 0.2	zero

TABLE XII
PRE-OPERATIONAL TRITIUM IN PRECIPITATION

LOCATION	DATE COLLECTED	TYPE	MEASURED RESULTS nCi/l±2σ	INTERPRETED RESULTS nCi/l
Eaton Farm	6/30/72	RAIN	0.40 ± 0.2	zero
Bailey Farm	6/30/72	RAIN	1.10 ± 0.2	1.1
Knight Cemetery	3/11/72	SNOW	0.26 ± 0.2	zero
Westport Firehouse	3/11/72	SNOW	0.17 ± 0.2	zero

2.232 Tritium in the Air Moisture

Tritium in the air moisture was measured in samples collected at the following three sites, Eaton Farm, 0.4 km, W.; Bailey Farm, 0.8 km, N.E.; and Westport Firehouse, 1.8 km, S. Air moisture samples were collected by drawing nominally 2000 liters of air through a plastic cylinder (8 cm diameter by 24 cm long) containing a desiccant[14]. The desiccant used was indicator type Dryrite. The cylinder of desiccant was weighed before the air was pulled through and weighed afterward to insure the collection of between twenty and thirty milliliters of air moisture. Nominal collection time was between two and four hours depending on the relative humidity. The desiccant cylinders were sealed and sent to the Eastern Environmental Radiation Facility in Montgomery, Alabama for tritium analysis. Water was exchanged with the desiccant moisture in a closed system. The resulting samples were processed for liquid scintillation tritium analysis in the usual way. The results of these measurements indicate the level for tritium in the air moisture was below the minimum detectable level of 0.2 nCi/l at all locations sampled on the data sampled (8/27/74).

2.233 Tritium in Precipitation

Tritium in precipitation was measured in two snow samples collected at Knight Cemetery, 1.1 km, E. on April 9, 1974 and rain samples collected at Eaton Farm, 0.4 km, W. and Bailey Farm, 0.8 km, N.E. on August 27, 1974. These samples were filtered in the same manner used for the water samples. (See section 2.22) Fifty milliliter samples were sent to the Eastern Environmental Radiation Facility, Montgomery, Alabama for tritium analysis using the liquid scintillation method. (See section 2.231) The results

of the analysis of tritium activity in the rain at Eaton Farm showed it to be below the minimum detectable level of 0.2 nCi/liter and the level at Bailey Farm to be 0.3 ± 0.2 nCi/liter, greater than the minimum detectable level. Tritium activity in the snow samples was below the minimum detectable level.

2.24 Discussion of Tritium Measurements

The purpose of tritium measurements in this study is to document typical values for the HTO component in water, air moisture and precipitation. In general the results of tritium analysis indicate no significant change. There is no evidence of an accumulation of tritium in the interchangeable environmental reservoirs such as wells, surface water or the Montsweag Bay estuary. Even though the Maine Yankee Environmental Impact Statement[2] lists a bioaccumulation factor of 1 for tritium, the authors feel that in light of the fact that tritium is one of the major radionuclide in the liquid and gaseous effluent, that tritium monitoring should be carried out on a regularly scheduled basis for a period of one half life (12.5 years) in order to check for possible long term accumulation. The only significant correlation between the pre-operational survey for tritium and the post-operational survey is that the rain samples at the Bailey Farm location contain tritium above the minimum detectable level. The large amount of tritium in the air moisture observed on 6/15/72 in the pre-operational survey was not observed in the post-operational study.

2.3 Radionuclides in Air Particulates

2.31 Field Air Particulate Measurements and Analysis

Radionuclides in air particulates were measured at three sites: Eaton Farm, Bailey Farm and Westport Firehouse. A Staplex large volume air sampler was used in conjunction with a 20.5 cm (8 1/16 inch) by 25.4 cm (10 inch) filter holder. Nuclear Associates, Inc. fiberglass filters number 08-780 were used. Approximately 3400 ft^3 of air were filtered at each site. The filter was folded three times (8 layers) and placed on the circular surface of the NaI(Tl) detector assemble used for the soil and sediment field measurements, and covered with a 3 cm lead shield. All air particulate field data were counted as soon after collection as possible (normally within a few minutes) on quarter memory (512 channels) for 2000 seconds. The multichannel analyzer was outputted on the teletype. Qualitative analysis snows that the bulk of the activity was due to daughters of ^{222}Rn and ^{220}Rn. After a period of 24 hours the activity of particulate on the filters was found to be long halflife radon daughters.

2.32 Laboratory Air Particulate Measurements

Air particulates for laboratory analysis were also collected at these same sites (Easton Farm, Bailey Farm, Westport Firehouse). A Millipore pump type XX6000000 was used to pull air through a 47 mm diameter Millipore absolute aerosol 0.8 μm filter, type AAWP4700. The throughput of this system was metered for all runs and a calibrated gas flow meter, American Meter Company Model 10-300-PR1264. The meter, pump, and filter holder were housed in an instrument box with a rubber hose from the filter holder to the outside. A nominal sampling time was 100 hours, with a nominal sampling

volume being 200,000 liters. The filters were weighed before and after collection. They were packaged carefully in separate plastic boxes and sent to the Eastern Environmental Radiation Facility, Montgomery, Alabama, for gamma-ray analysis. Each sample was counted for gamma-rays in the 40 ml NaI(Tl) well-counter which is 11 cm x 15 cm and has a 3 cm well. The results of these measurements are given in Table XIII. The gross-alpha measurements were counted in an internal proportional counter and the gross-beta measurements were counted in a low background beta counter. The results of these measurements are also given in Table XIII. The pre-operational measurements are listed in Table XIV.

Discussion of the Air Particulate Results

The short term field air particulate collections and measurements reveal the presence of ^{220}Rn and ^{222}Rn as the most important source of activity, essentially identical to the pre-operational study of 1972.

Large volume laboratory air particulate measurements as presented in TABLES XIII and XIV show no significant changes.

2.4 High Pressure Ion Chamber

2.41 High Pressure Ion Chamber Measurements

High pressure ion chamber measurements had been carried out in 1971 by Wesley R. Van Pelt of Environmental Analysis, Inc. for Maine Yankee. Due to the relevance for population dose calculations and for comparison with the gamma-ray field studies, high pressure ion chamber measurements were carried out in collaboration with Mr. Charles Phillips of the Eastern Environmental Radiation Facility, Montgomery, Alabama. Both studies employed calibrated Reuter Stokes high pressure ion chambers. In the present study the ion chamber was RSS-111 (Reuter Stokes environmental monitor), with Rustrak Recorder. The monitor was placed 1 meter above the surface at 11 soil sites and 2 sediment sites. The soil sites were Foxbird Island, 0.1 km, S.; Eaton Farm, 0.4 km, W.; Bailey Farm, 0.8 km, N.E.; Young's Creek, 1.0 km, N.; Knight Cemetery, 1.1 km, E.; Westport Firehouse, 1.8 km, S.; Chewonki Neck (Camp) 1.9 km, S.W.; Cowseagan Narrows, 3.2 km, N.E.; Bluff Head, 4.0, S.S.W.; Cromwells 1.0 km, E.; and sediment sites Foxbird Island, 0.1 km, S.; and Murphy's Corner, 2.8 km, S.W.. The results of these measurements are shown in Table XV. Table XV lists high pressure ion chamber measurements of dose rate (μR/hr) for the post-operational and pre-operational[15] surveys. The most significant change occured at the

Foxbird Island (sediment) site at 42 percent increase in dose rate was measured. The last column lists post-operational calculated dose rate based upon laboratory measurement of specific activity for all significant gamma emitting radionuclides observed. The method used, due to Beck, is discussed in Appendix C[16].

TABLE XIII
POST-OPERATIONAL AIR PARTICULATE ANALYSIS

LOCATION	COLLECTION DATE	AIR VOLUME LITERS	PARTICULATE MASS (GRAMS)	α-ACTIVITY pCi/FILTER ±2σ	β-ACTIVITY pCi/FILTER ±2σ	γ-ACTIVITY pCi/FILTER ±2σ
Bailey Farm	8/19/74	166,230	0.016 ± 0.001	5.3 ± 68%	29.3 ± 73%	34 ± 37% (^{7}Be)
Eaton Farm	8/22/74	197,350	0.004 ± 0.001	6.0 ± 70%	25.4 ± 10%	4 ± 18% (^{95}ZrNb)
Westport Firehouse	8/27/74	191,960	0.005 ± 0.001	7.7 ± 55%	4.4 ± 11%	NONE

TABLE XIV
PRE-OPERATIONAL AIR PARTICULATE ANALYSIS

LOCATION	COLLECTION DATE	AIR VOLUME LITERS	PARTICULATE MASS (GRAMS)	γ-ACTIVITY ZrNb	γ-ACTIVITY (^{7}Be)
Bailey Farm	6/19/72	97,740	0.002 ± 0.001	<15 pCi ZrNb	<200 pCi
Eaton Farm	7/5/72	86,730	0.001 ± 0.001	< 5 pCi	< 50 pCi
Westport Firehouse	6/29/72	101,810	0.004 ± 0.001	<15 pCi	<200 pCi

TABLE XV
COMBINED PRE-OPERATIONAL AND POST-OPERATIONAL
HIGH PRESSURE ION CHAMBER MEASUREMENTS

SITE NAME (measured over soil unless otherwise noted)	POST-OPERATIONAL MEASUREMENTS DATE	POST-OPERATIONAL DOSE RATE µR/hr	PRE-OPERATIONAL MEASUREMENTS DATE	PRE-OPERATIONAL DOSE RATE µR/hr	POST-OPERATIONAL CALCULATED DOSE RATE (µR/hr)
Foxbird Island	8/24/74	10.1	-	-	8.9
Eaton Farm	8/22/74	10.2	9/20/71	9.5	12.0
Bailey Farm	8/22/74	9.7	9/20/71	9.5	12.0
Young's Creek	8/22/74	9.7	-	-	11.7
Knight Cemetery	8/22/74	11.2	-	-	13.0
Westport Firehouse	8/22/74	9.5	9/21/71	11.4	9.6
Chewonki Neck Camp	8/22/74	9.9	-	-	10.2
Cowseagan Narrows	8/22/74	10.2	-	-	10.9
Bluff Head	8/22/74	10.8	-	-	12.3
Foxbird Island (sediment)	8/24/74	12.6	9/21/71	7.3	14.51
Murphy's Corner (sediment)	8/22/74	8.9	9/21/71	7.91	10.8
Cromwells	8/22/74	9.1	-	-	-

APPENDIX A

LIQUID EFFLUENT INVENTORY IN CURIES

TABLE XVI

	JULY-DEC 72	JAN-JUNE 73	JULY-DEC 73	JAN-JUNE 74	JULY-DEC 74	
^{140}BaLa	NDA	NDA	NDA	6.09×10^{-5}	NDA	6.09×10^{-5}
^{133}I	NDA	NDA	NDA	2.93×10^{-3}	-	2.93×10^{-3}
^{131}I	4.12×10^{-3}	1.62×10^{-3}	4.12×10^{-3}	2.76×10^{-1}	8.20×10^{-2}	0.37
^{133}Xe	1.49×10^{-3}	7.05×10^{-2}	1.49×10^{-3}	11.7	1.04×10^{-2}	11.78
^{135}Xe	NDA	NDA	NDA	7.78×10^{-3}	NDA	7.78×10^{-3}
^{137}Cs	NDA	NDA	NDA	6.15×10^{-3}	9.81×10^{-1}	9.9×10^{-1}
^{134}Cs	NDA	NDA	NDA	2.53×10^{-3}	7.31×10^{-1}	7.3×10^{-1}
^{60}Co	2.04×10^{-4}	3.34×10^{-3}	2.04×10^{-4}	5.41×10^{-3}	1.46×10^{-2}	2.3×10^{-2}
^{58}Co	5.48×10^{-3}	6.56×10^{-2}	5.48×10^{-3}	2.17×10^{-2}	2.60×10^{-1}	3.58×10^{-1}
^{51}Cr	NDA	2.68×10^{-2}	NDA	3.78×10^{-2}	-	4.04×10^{-1}
^{54}Mn	8.06×10^{-4}	1.12×10^{-2}	8.06×10^{-4}	1.99×10^{-3}	NDA	1.48×10^{-2}
^{103}Ru	NDA	NDA	NDA	NDA	-	NDA
^{90}Sr	LOST	NDA	LOST	1.40×10^{-5}	NDA	1.40×10^{-5}
^{99}Mo	1.5×10^{-5}	NDA	1.50×10^{-5}	2.30×10^{-3}	-	2.33×10^{-3}
^{95}Zr	-	3.1×10^{-3}	-	1.54×10^{-3}	-	4.64×10^{-3}
^{95}Nb	-	2.9×10^{-3}	-	2.62×10^{-3}	-	5.52×10^{-3}
^{59}Fe	-	5.95×10^{-3}	-	-	1.19×10^{-3}	7.14×10^{-3}
^{97}Zr	1.5×10^{-5}	-	1.5×10^{-5}	-	-	3.0×10^{-5}
UN	1.34×10^{-3}	-	-	-	-	1.34×10^{-3}
^{133m}Xe	-	-	-	6.48×10^{-5}	-	6.48×10^{-5}
^{57}Co	-	-	-	9.38×10^{-6}	NDA	9.38×10^{-6}
^{89}Sr	-	-	-	-	2.94×10^{-5}	2.94×10^{-5}
^{3}H	9.22	75.67	77.9	115	104	3.81×10^{2}

TABLE XVI

GASEOUS EFFLUENT INVENTORY IN CURIES

	OCT-DEC 72	JAN-JUNE 73	JULY-DEC 73	JAN-JUNE 74	JULY-DEC 74
^{137}Cs	NDA	NDA	NDA	3.51×10^{-5}	NDA
$^{140}BaLa$	NDA	NDA	NDA	NDA	NDA
^{90}Sr	NDA	NDA	NDA		-
^{134}Cs	NDA	NDA	NDA	1.37×10^{-5}	NDA
^{89}Sr	-	-	-	-	-
^{58}Co	-	3.9×10^{-6}	8.91×10^{-5}	2.3×10^{-5}	3.32×10^{-4}
^{60}Co	-	-	-	5.1×10^{-6}	1.72×10^{-4}
^{54}Mn	-	-	-	-	NDA
^{110}Ag	-	-	-	-	NDA
^{57}Co	-	-	-	2.2×10^{-8}	2.10×10^{-5}
^{99}Mo	-	-	-	2.9×10^{-6}	2.90×10^{-6}
^{131}I	1.71×10^{-6}	9.39×10^{-6}	1.62×10^{-3}	6.58×10^{-2}	4.98×10^{-2}
^{133}I	NDA	NDA	3.28×10^{-4}	3.00×10^{-2}	1.48×10^{-3}
^{135}I	NDA	NDA	NDA	5.79×10^{-3}	NDA
^{85}Kr	2.05	6.3×10^{-3}	1.505	3.50×10^{2}	4.36×10^{2}
^{133}Xe	NDA	6.36	151.56	3.81×10^{3}	2.41×10^{3}
^{88}Kr	NDA	NDA	NDA	NDA	NDA
^{87}Kr	NDA	NDA	NDA	NDA	NDA
^{138}Xe	NDA	NDA	NDA	NDA	NDA
^{135m}Xe	NDA	NDA	NDA	-	NDA
^{41}Ar	7.1×10^{-2}	NDA	1.00×10^{-1}	NDA	NDA
^{133m}Xe	-	-	-	NDA	3.30
^{131m}Xe	-	8.9×10^{-2}	NDA	4.91×10^{1}	7.78×10^{1}
^{88}Rb	NDA	NDA	-	NDA	-
^{85m}Kr	-	NDA	NDA	NDA	NDA
^{135}Xe	-	-	1.27×10^{-1}	1.90×10^{2}	5.50×10^{-1}
^{51}Cr	-	-	-	8.4×10^{-6}	-
^{95}Nb	-	-	-	1.78×10^{-6}	-

APPENDIX B

PRE-SCAN RESULTS

The purpose of a pre-scan is to determine the optimum locations for the field studies. For this reason, the pre-scan was planned to take place early in the field studies and to provide usable results during the first week of the study. As is mentioned in section 2.11 of off-site soil measurements and their analysis, gamma-ray pre-scans were taken on kilogram samples from nine soil and two sediment sites. Samples were counted for 5000 seconds using the University of Maine Department of Physics Ge(Li) detector with low background shield. The lists of counts were then compared with lists of counts taken on pre-operational samples, collected in 1972. The examination of these lists provided the information for choosing the field locations. Later, punched tapes of these spectra were analyzed at the University of Maine Computer Center. The results of these analysis are shown in Table XVIII. Radionuclide concentrations are shown in picocuries per kilogram of sample. The first five columns of this table contain concentrations of natural isotopes: ^{228}Ac, ^{208}Tl of the Thorium series, ^{214}Pb, ^{214}Bi of the Urnaium series, and ^{40}K. The remaining columns of concentrations are of man-made fallout or reactor origin. Trace amounts of ^{46}Sc or ^{65}Zn were observed at Foxbird Island, Eaton Farm, Bailey Farm, Young's Creek, Knight Cemetery, Bluff Head, and Murpny's Corner, but could not be quantitatively determined due to interference from ^{214}Bi. The radionuclides ^{95}Nb-^{95}Zr (200 pCi/kg) were observed at Foxbird Island, Bailey Farm, Young's Creek, Knight Cemetery, Westport Firehouse, Bluff Head, Murphy's Corner and Foxbird Island sediment, and ^{131}I (300 pCi/kg) may have been observed in Murphy's Corner sediment. Errors are quoted under each number and represent $\pm 1\sigma$.

The site which showed largest amounts of man-made radionuclides was

Foxbird Island (sediment). There was on archival pre-scan result for this sample and Murphy's Corner sediment since there were no archival samples. In all other cases, pre-operational and post-operation samples were available and results are given in pairs in the table. Dashes in the table mean that results were below the minimum detectable limit. As a result of studying the pre-scan results (using the original lists) we selected for field studies: Foxbird Island soil and sediment, Eaton Farm, Bailey Farm, Knight Cemetery, soils and Murphy's Corner sediment.

TABLE XVIII PRE-SCAN RADIONUCLIDES pCi/kg ± 1σ

LOCATION	DATE OF COLLECTION	DATE OF MEASUREMENT	TYPE	^{228}Ac	^{208}Tl	^{214}Pb	^{214}Bi	^{40}K	^{137}Cs	^{58}Co	^{60}Co	^{134}Cs	^{54}Mn
Foxbird	6/29/72	8/15/73	soil	600 ±400	600 ±200	1000 ±100	700 ±200	11000 ±1000	800 ±100	-	-	200 ±60	-
Island	8/14/74	8/17/74	soil	600 ±400		700 ±500	700 ±200	10000 ±1000	5400 ±400	-	60 ±30	-	-
Eaton	6/12/72	8/14/73	soil	1100 ±200	1400 ±200	1100 ±200	900 ±100	15000 ±1200	1900 ±100	-	-	600 ±80	20 ±30
Farm	8/14/74	8/19/74	soil	1300 ±300	1200 ±200	1400 ±200	800 ±200	15000 ±1200	1900 ±100	-	-	400 ±70	-
Bailey	6/12/72	8/14/73	soil	1400 ±300	1600 ±200	2000 ±200	900 ±100	17000 ±1400	1300 ±100	-	-	200 ±60	-
Farm	8/14/74	8/17/74	soil	700 ±200	700 ±200	1000 ±100	800 ±100	15000 ±1200	1800 ±100	-	-	300 ±60	-
Young's	6/12/72	8/16/73	tidal marsh soil	1200 ±200	1400 ±200	1600 ±200	800 ±100	18000 ±1100	500 ±100	-	-	100 ±100	-
Creek	8/14/74	8/19/74	tidal marsh	1400 ±300	1800 ±300	1000 ±100	800 ±200	14000 ±1300	800 ±100	80 ±50	-	300 ±60	-
Knight	6/12/72	9/21/73	soil	2400 ±400	1600 ±200	1600 ±200	1400 ±300	13000 ±1400	6200 ±300	-	70 ±50	300 ±60	-
Cemetery	8/14/74	8/17/74	soil	1700 ±500	1400 ±200	1400 ±200	1100 ±200	10000 ±1200	3600 ±200	-	60 ±50	600 ±80	-
Westport	6/12/72	8/17/73	soil	1100 ±200	800 ±200	1700 ±200	1000 ±100	10000 ±900	1300 ±100	-	40 ±50	300 ±60	-
Firehouse	8/14/74	8/19/74	soil	400 ±200	1100 ±200	1200 ±200	700 ±200	11000 ±1300	2200 ±200	50 ±50	30 ±20	300 ±60	-
Chewonki	6/12/72	9/19/73	soil	1300 ±300	1300 ±300	1500 ±200	1200 ±200	16000 ±1400	5000 ±300	-	160 ±70	100 ±30	-
Neck Camp	8/14/74	8/20/74	soil	600 ±200	700 ±200	800 ±100	600 ±200	10000 ±1200	1700 ±100	-	90 ±44	300 ±60	-
Cowseagan	6/13/72	8/17/73	soil	700 ±300	900 ±300	1600 ±200	800 ±200	17000 ±1700	4000 ±200	120 ±64	40 ±50	200 ±60	-
Narrows	8/14/74	8/19/74	soil	1000 ±200	1100 ±200	1700 ±200	700 ±100	10000 ±1000	-	-	30 ±50	81 ±20	25 ±30
Bluff	6/12/72	8/21/73	soil	1900 ±300	1100 ±200	2000 ±200	1600 ±200	12000 ±1100	2500 ±200	80 ±50	-	100 ±30	-
Head	8/14/74	8/17/74	soil	1300 ±300	1500 ±200	1300 ±200	1100 ±200	12000 ±1100	1800 ±200	-	-	400 ±70	20 ±30
Murphy Corner	8/14/74	8/20/74	Sed.	1100 ±200	1100 ±200	1300 ±200	1000 ±200	12000 ±1000	400 ±200	100 ±40	20 ±30	400 ±70	-
Foxbird Island	8/14/74	8/20/74	Sed.	600 ±100	1400 ±300	2300 ±700	2000 ±200	8000 ±900	910 ±100	19000 ±400	800 ±100	1000 ±80	200 ±60

APPENDIX C

Calculation of Dose Rate at One Meter from Gamma-Ray Emitting Soils and Sediments

Calculation of gamma-ray dose rate due to a plane source such as soil or sediment is of practical importance. The factors for conversion from the isotope concentration of the plane medium to dose at one meter above the surface for ^{40}K, ^{137}Cs, ^{60}Co, ^{232}Th-series and ^{238}U-series are found in a paper due to Beck[16,17]. Two new factors, using Beck's Table 7 and branching ratios from the literature, are calculated for ^{58}Co and ^{134}Cs. These eight factors are presented in Table XIX. Dose Calculations for eleven sites are presented in Table XV. The cosmic ray contribution is included using ionization chamber data gathered by W. Van Pelt[15] over water in 1971.

TABLE XIX

Factors for Computation of Dose Rate at 1 Meter due to Gamma-Ray Emitting Radionuclides in Soil and Sediment

Isotope		Factor
Natural		(μR/h per pCi/g)
	^{40}K	0.179
	^{238}U-Series	1.82
	^{232}Th-Series	2.82
Man Made		(μR/h per mCi/km^2) X10^{-3}
	^{137}Cs	4.29
	^{58}Co	7.25
	^{60}Co	18.0
	^{54}Mn	6.3
	^{134}Cs	11.4

TABLE XX

POST-OPERATIONAL LABORATORY RESULTS USED IN CALCULATION OF DOSE RATE (μR/h) 1 METER ABOVE GROUND

LOCATION	^{40}K	^{238}U-series	^{232}Th-series	^{137}Cs	TOTAL GAMMA-RAY DOSE RATE	COSMIC RAY*	GRAND TOTAL†
Foxbird Island (soil)	1.30	1.24	2.53	.22	5.29	3.60	8.89
Eaton's Farm (soil)	3.14	2.00	3.10	.12	8.36	3.60	11.96
Bailey's Farm	3.15	2.00	3.10	.05	8.30	3.60	11.90
Young's Creek (soil)	3.47	1.45	3.10	.03	8.05	3.60	11.65
Knight Cemetery (soil)	2.02	2.36	4.79	.19	9.36	3.60	12.96
Westport Firehouse (soil)	2.11	1.45	2.25	.15	5.96	3.60	9.56
Chewonki Neck (Camp) (Soil)	2.70	1.27	2.53	.07	6.57	3.60	10.17
Cowseagan Narrows (soil)	2.55	1.82	2.82	.06	7.25	3.60	10.85
Bluff Head (soil)	2.38	2.91	3.38	.06	8.73	3.60	12.33
Foxbird Island (sed.)	3.67	1.64	2.54	.06	7.91	3.60	14.45
Murphy's Corner (sed.)	3.22	1.45	2.53	.02	7.20	3.60	10.80

*Taken over water in 1971 by W. Van Pelt

†Including ^{134}Cs, ^{58}Co, ^{60}Co and ^{54}Mn (2.93μR/h)

APPENDIX D

A Model for Radionuclides in Oysters and Associated Sediments*

INTRODUCTION

The variation of the concentration of gamma-ray emitting radionuclides has been observed and modeled in a stable population of American oysters (C. virginica), and associated estuarine sediments during 12 months at four sites in the Montsweag Estuary in the effluent of the Maine Yankee Nuclear Power Reactor and at a control site in the Damariscotta Estuary. Gamma-ray peaks have been observed at 0.810 MeV (^{58}Co), 1.173 and 1.332 MeV (^{60}Co), 1.732 (^{40}K), 0.835 MeV (^{54}Mn), 0.765 MeV (^{95}Nb), 0.238 MeV (^{212}Pb), and 0.662 MeV (^{137}Cs) using a Ge(Li) detector. The concentration of the most abundant man-made isotopes ^{58}Co, ^{60}Co, and ^{54}Mn have been compared at selected sites with a mathematical model for the accumulation and loss of these nuclides by the oysters and sediments.

PREVIOUS WORK

Radionuclide accumulation and loss have been studied in oysters by Seymour[18], Jefferies and Preston[19], Naidu and Seymour[20], Nelson and Seymour[21], Wolf[22], Lowman, Rice and Richards[23]; and radionuclide accumulation has been studied in sediments by Heft, Phillips, Ralston, and Steel[24], Noshkin and Bowen[25] and Lentsch, et. al.[26] among others. Models, field studies and laboratory studies of accumulation and depuration have been undertaken for radionuclides in reactor effluent for ^{137}Cs and ^{60}Co in the marine clam, Harrison[27]; ^{58}Co in the mussel, Mytilus edulis, Shimizu et. al.[28]; Teleost and Elasmobranch fish, Pentreath[29], and for several organisms by Lowman, et. al.[30].

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Mathematical models for accumulation of radionuclides, are usually based on a constant source of radionuclides, a condition which is generally convenient and applicable for laboratory studies however, must provide for the time variation of the sources of radionuclides since in the case of nuclear reactors the liquid, radionuclide effluents are usually released according to some schedule with waiting periods between releases, as discussed by Heft et.al.[24]. This variation of source intensity can be included in the mathematical model by driving the first order linear differential equation for accumulation and decay with a time varying function representing the release schedule[1]. This model corresponds mathematically to an impulsively driven relaxator with characteristic relaxation times for the various mechansims of accumulation and decay.

EXPERIMENTAL DESIGN

Five groups of American oysters were grown: 4 Montsweag Estuary locations (intake of the reactor S1, outflow of the reactor S2, upper cove S3 and 0.58 km, N., Long Ledge S4, 1.29 km. S.) and at a control site located on the Damariscotta Estuary S5. At approximately two month intervals, the live oysters were removed from their trays, and transported to the Ge(Li) detector enclosed in a low background shield. Approximately 1 liter of live oysters were counted for 5000 seconds and the resulting data were computer processed using the Compton continuum subtraction method[8]. After counting, the cysters were returned to their original locations. The concentrations of radionuclides were determined using standard techniques to calibrate the multichannel analyzer-detector-shield system.

Seven sediment sites were chosen (intake sediment M1, outflow M2, Upper cove M3, Long Ledge M4, Murphy Corner, M5, 2.98 km S.W., Oak Island M6, 2.90 km S.W., and Bluff Head M7, 4.39 km S.W.) At approximately two month intervals, 2 Kg sediment samples were collected at each of the sites and gamma-ray analyzed in the same manner as the oysters.

THEORY

The uptake of radionuclides may be described by a first order linear differential equation

$$\frac{dN}{dt} = -\lambda N + R(t), \qquad 1)$$

where $\frac{dN}{dt}$ is the rate of increase in atoms of nuclide N, λN is the rate of loss due to radioactive decay, and R(t) is the rate of introduction of nuclides from an external source (i.e. the nuclear reactor release schedule)[1]. Depuration is included by writing a term $\lambda_p N$ which describes the ("Biological Decay") observed experimentally by Seymour[18].

$$\frac{dN}{dt} + \lambda N + \lambda_p N = R(t). \qquad 2)$$

The solution to Eq. 1 may be written

$$N = e^{-\lambda t} \int e^{\lambda t} R(t)\, dt + ce^{-\lambda t}. \qquad 3)$$

We assume that releases of nuclides are made on a sequence of m times, $\{t_1, t_2, t_3, \ldots\ldots\ldots t_m\}$ and the amount of nuclide released is given by a function f(t) which for times greater than or equal to t_1 but less than t_2 is given by $f_1\delta(t-t_1)$, and for times greater than or equal to t_2 but less than t_3 by $f_2\delta(t-t_2)$ and so on up to times greater than t_m. The fraction of the nuclide which was released and is retained is given by U, so that for the accumulation N(t)

$$N(t) = e^{-\lambda t} \int_{0}^{t_1+\varepsilon} e^{\lambda t} f_1 \delta(t-t_1)\, U dt + \ldots.$$

$$+ e^{-\lambda t} \int_{t_m-1+\varepsilon}^{t_m+\varepsilon} e^{\lambda t} f_m \delta(t-t_m)\, U\, d\, t + c\, e^{-\ t}. \qquad 5)$$

If U. is a constant ratio of retention for all time, we can construct a table of functions for the times between the release time.

$$\begin{aligned} &0 \leq t \leq t_1 && N(t) = ce^{-\lambda t} \\ &t_1 \leq t \leq t_2 && N(t) = Uf_1 e^{-\lambda(t-t_1)} + ce^{-\lambda t} \\ &t_2 \leq t \leq t_3 && N(t) = Uf_2 e^{-\lambda}(t-t_2) + Uf_1 e^{-\lambda(t-t_1)} + ce^{-\lambda t} \end{aligned} \qquad 6)$$

These equations may be interpreted as a gradual decay of isotopes from the release-time until the next release-time. Sudden increases occur at each release-time. Graphs of two typical cases are shown in Fig. 5, which shows the results for a half life (^{58}Co) comparable to two release intervals, as well as a half life (^{60}Co) comparable to 60 release intervals.

OYSTER RESULTS

The concentration expressed in pCi of the radionuclide ^{58}Co is shown per gram of oysters in Fig. 6. The broken lines represent the experimental values for this isotope in the four Montsweag Estuary sites and the Damariscotta Estuary control site from June 73 through July 74. The theoretical results are shown with a solid line from May 73 through June 74. The same peak found in the theory is evident at the outflow, Long Ledge and intake sites and a small increase may be seen in the control site in October. The best agreement occurs (comparison may be made) between the outflow site and the theory. It is evident that the oysters show a faster decrease in activity in Dec. 73 through Feb. 74 than that predicted by theory. This may be

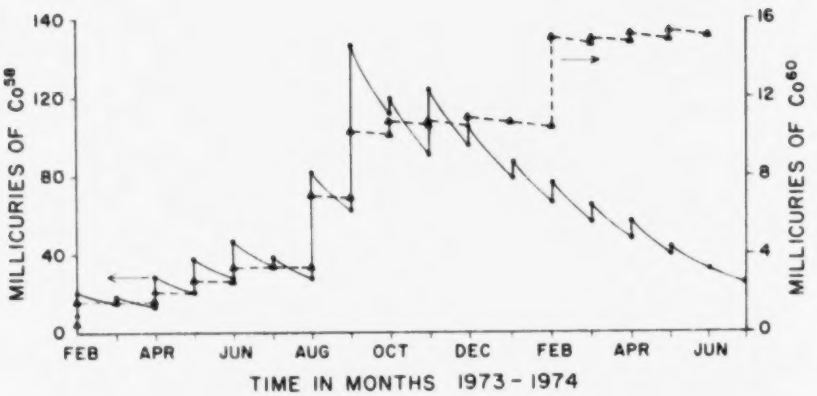

Figure 5. Calculated Accumulation of ^{58}Co and ^{60}Co as a Function of Time

The solid line shows the theoretical accumulation of ^{58}Co in millicuries versus month of year from Feb. 1973 through July, 1973. The dashed line shows the theoretical accumulation of ^{60}Co in millicuries versus month of the year from Feb. 1973 through June, 1974.

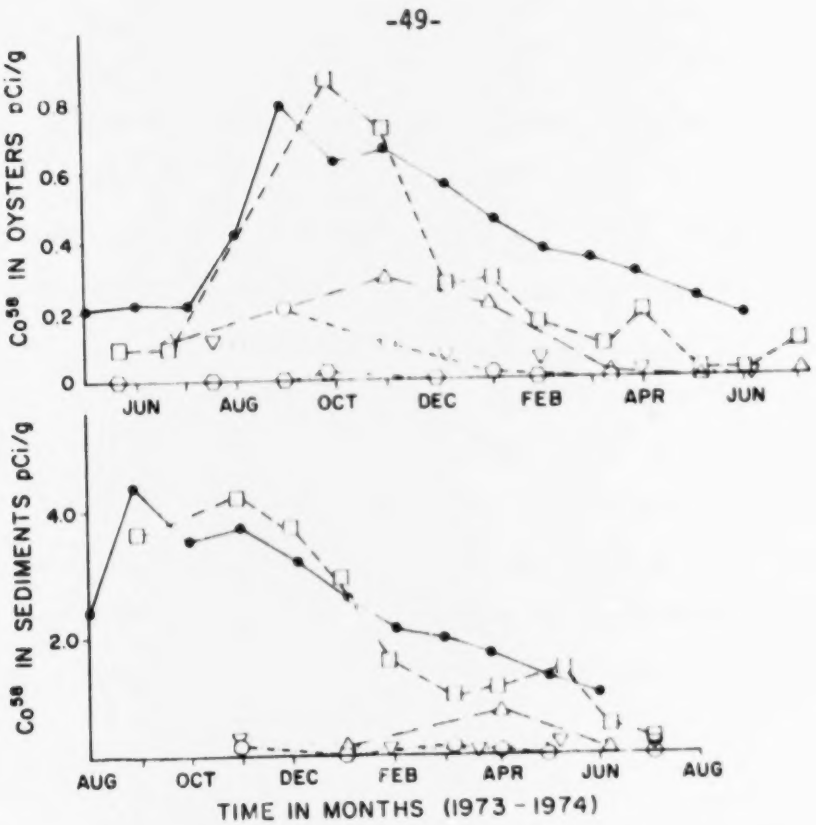

Figure 6. Calculated and Measured Accumulation of ^{58}Co as a Function of Time

The upper half shows the radionuclide ^{58}Co in oysters at site S1 (intake) triangle and dot-dash, site S2 (outflow) square and dash, site S3 (Upper cove) circle and dot-dash, site S4 (Long Ledge) triangle and dot, SC (control site) hexagon dash-dot-dot, and theoretical curve for outflow site with filled circle and solid line, versus time in months, for the years 1973-1974. The lower half shows the radionuclides ^{58}Co in sediments at sediments sites M1 (intake) with triangle dash-dat, M2 (outflow) with square dash, M3 (Upper cove) circle dash-dot, M4 (Long ledge) with triangle dot and theoretical curve for outflow site with cricle solid line versus time in months from Aug. 1973-July, 1974.

explained as the depuration of isotopes from the oysters during these months.

The concentration of the radionuclide ^{54}Mn for the outflow site was found to be practically flat during this time and compare favorably with theory within statistical errors in the measurement. In addition to the ^{58}Co and ^{54}Mn results, small amounts of ^{60}Co are observed in Oct. 73 at the outflow, Jan. 74 at Long Ledge and Oct. 73 and Jan. 74 at Upper Cove. Small amounts of ^{54}Mn is also observed on July 73, Dec. 73 and Jan. 74 at Long Ledge and Jan. 74 at the control site. The naturally occurring isotope ^{40}K is observed at all sites for all measurements and its variation is correlated with variation in the salinity.

SEDIMENT RESULTS

The concentration expressed in pCi of ^{58}Co per gram of sediments is shown in Fig. 6. The broken lines represent the experimental values for this isotope in four Montsweag Estuary sites from Sept. 73 through July 74. The solid line represents the theory for the time from Aug. 73 through June 74. The best comparison can be made fro the outflow site which has the largest concentration and shows a broad peak in the months Sept. 73 through Jan. 74. The decrease of ^{58}Co during Jan - Feb. 74, is more rapid than theory predicts and represents depuration due to loss of radioactivity from the sediments. The other sites had a factor of 10 less isotope than this site, and insufficient data for further conclusions.

The radionuclides ^{40}K, ^{58}Co, ^{60}Co, ^{54}Mn observed in the outflow sediment may be averaged, and compared. These radionuclides are expressed in picocuries/gram of sediment and are averaged for monthly values for the time period Aug. 73 - March 74. The average values in order of decreasing concentration are ^{40}K, 5.7 pCi/gm, ^{58}Co, 4.9 pCi/gm, ^{60}Co, 0.8 pCi/gm,

and ^{54}Mn, 0.2 pCi/gm. All of these isotopes have maximum values in the month of Nov. 73. Most of the isotopes show a decrease in the month of Dec. 73 which is correlated with a salinity drop in the estuary. The decreases in both ^{60}Co and ^{54}Mn may be interpreted as the combined effect of radioactive decay and depuration. The effective depuration rate for the outflow sediment during this time was 150 ± 30 days for ^{60}Co. The depuration rate for the ^{54}Mn is 180 ± 50 days.

The radionuclides ^{95}Nb, ^{212}Pb, ^{137}Cs in the outflow sediment may also be averaged and compared. In order of decreasing concentration, these are ^{95}Nb, 0.8 pCi/gm, ^{212}Pb, 0.4 pCi/gm and ^{137}Cs, 0.2 pCi/gm. These radionuclides show a maximum during the month of Nov. 73 for ^{95}Nb and March 74 for the ^{212}Pb and ^{137}Cs. Since the initial values of ^{212}Pb, ^{137}Cs and $^{95}Nb^{95}Zr$ in soil and sediments measured prior to the plant operations were large, comparison with theory is not attempted for these nuclides. The sediment sites, M5 M6, and M7 showed only ^{40}K, ^{212}Pb and ^{137}Cs.

DETERMINATION OF UPTAKE RATIO U

Since theory and experiment seem to agree, it is possible to divide the radionuclide in oysters or sediments (Fig. 6) by the calculated accumulation (Fig. 5) to form an uptake ratio U. The values for U indicate that most of the radioactivity is concentrated in the region of outflow, decreasing rapidly with distance. There is also variation of concentration from radionuclide to radionuclide with ^{58}Co strongest, ^{60}Co weaker and ^{54}Mn weakest for both sediments and oysters.

SUMMARY OF APPENDIX D

Oysters have been grown in the effluent of a nuclear reactor and have been used in a longitudinal study of radionuclide uptake and depuration. The radionuclides ^{58}Co, ^{60}Co and ^{54}Mn have been observed experimentally in the oysters and associated sediments. At selected sites, the variation of radionuclides in both oysters and sediments was found to be in good agreement with predictions of a mathematical model, which incorporates radioactive decay and a time dependent driving source of radionuclides due to the liquid effluent release from the reactor. Values for an average uptake ratio U, are then calculated for selected sites. Maximum values of ^{58}Co of 800 pCi/kg results in an annual dose rate of 0.27 mrem/year. Maximum values of ^{54}Mn of 12 pCi/kg results in an annual dose rate of 0.004 mrem/year.

PRE-OPERATIONAL LABORATORY WATER GAMMA-RAY ANALYSIS
OF THE DISSOLVED COMPONENT

APPENDIX E

TABLE XXI

LOCATION	TYPE	DATE COLLECTED	DATE COUNTED	^{40}K gm/l±2σ	^{137}Cs pCi/l±2σ	^{222}Rn pCi/l±2σ
Foxbird Island	estuarine	6/13/72	6/22/72	0.18 ±0.06	<2.0	<4.0
Eaton Farm	well	/13/72	6/22/72	<0.10	<2.0	<4.0
Bailey Farm	well	6/13/72 6/13/72	6/22/72 6/29/72	<0.10 <0.10	<2.0 <2.0	81.0 ± 13.0 <4.0
Young's Creek	surface	6/13/72	6/22/72	<0.10	<2.0	<4.0
Chewonki Neck(Camp)	well	6/13/72 6/13/72	6/22/72 6/27/72	<0.10 <0.10	<2.0 <2.0	98.2 ± 19.2 <4.0
Cowseagan Narrows	estuarine	6/13/72	6/22/72	0.19 ±0.06	<2.0	<4.0
Bluff Head	estuarine	6/13/72	6/22/72	0.16 ±0.06	<2.0	<4.0

(All samples were counted for 50 minutes in a 3.5 liter Marinelli beaker geometry)

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